Chapter 7. Bioaccumulation of Contaminants in Fish Tissues

INTRODUCTION

Bottom dwelling (i.e., demersal) fishes are collected as part of the South Bay Ocean Outfall (SBOO) monitoring program to assess the accumulation of contaminants in their tissues. The bioaccumulation of contaminants in a fish occurs through biological uptake and retention of chemical contaminants derived from various exposure pathways (Tetra Tech 1985). Exposure routes for demersal fishes include the uptake of dissolved chemical constituents from the water and the ingestion and assimilation of pollutants from food sources. Because of their proximity to the sediments, they also accumulate pollutants by ingesting pollutant-containing suspended particulate matter or sediment particles. For this reason, levels of contaminants in tissues of demersal fish are often related to those found in the environment (Schiff and Allen 1997), thus making them useful in biomonitoring programs.

The bioaccumulation portion of the SBOO monitoring program consists of 2 components: (1) liver tissues are analyzed from trawl-caught fishes; (2) muscle tissues are analyzed from fishes collected by rig fishing. Fishes collected from trawls are considered representative of the demersal fish community, and certain species are targeted based on their ecological significance (i.e., prevalence in the community). Chemical analyses are performed using livers because this is the organ where contaminants typically concentrate. In contrast, fishes targeted for collection by rig fishing represent species from a typical sport fisher's catch, and are therefore of recreational and commercial importance. Muscle tissue is analyzed from these fish because it is the tissue most often consumed by humans, and therefore the results have human health implications.

All muscle and liver samples were analyzed for contaminants as specified in the NPDES discharge permits governing the SBOO monitoring program. Most of these contaminants are also sampled for the NOAA National Status and Trends Program. NOAA initiated this program to detect changes in the environmental quality of our nation's estuarine and coastal waters by tracking contaminants thought to be of concern for the environment (Lauenstein and Cantillo 1993). This chapter presents the results of all tissue analyses that were performed during 2006.

MATERIALS AND METHODS

Collection

Fishes were collected during the April and October surveys of 2006 at 7 trawl and 2 rig fishing stations (**Figure 7.1**). Trawl-caught fishes were collected, measured, and weighed following guidelines described in Chapter 6 of this report. Fishes targeted at the rig fishing sites were collected using rod and reel fishing tackle, and then measured and weighed.

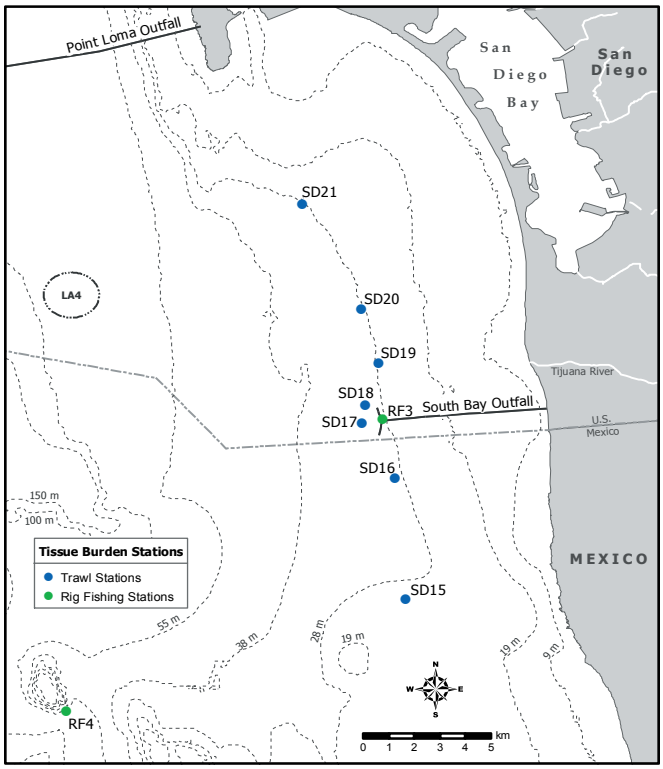

Figure 7.1
Otter trawl and rig fishing station locations for the South Bay Ocean Outfall Monitoring Program.

Table 7.1

Species collected at each SBOO trawl and rig fishing station during April and October 2006.

Station	Rep 1	Rep 2	Rep 3
April 2006			
SD15	Hornyhead turbot	(no sample)	(no sample)
SD16	Hornyhead turbot	Longfin sanddab	English sole
SD17	Hornyhead turbot	Longfin sanddab	English sole
SD18	Hornyhead turbot	English sole	Longfin sanddab
SD19	Hornyhead turbot	English sole	Longfin sanddab
SD20	Hornyhead turbot	English sole	Longfin sanddab
SD21	Longfin sanddab	Hornyhead turbot	English sole
RF3	Brown rockfish	Brown rockfish	Brown rockfish
RF4	California scorpionfish	California scorpionfish	California scorpionfish
October 2006			
SD15	Hornyhead turbot	Pacific sanddab	Hornyhead turbot
SD16	Longfin sanddab	Hornyhead turbot	Hornyhead turbot
SD17	California scorpionfish	California scorpionfish	Hornyhead turbot
SD18	California scorpionfish	Hornyhead turbot	Hornyhead turbot
SD19	Hornyhead turbot	Hornyhead turbot	Longfin sanddab
SD20	Longfin sanddab	Hornyhead turbot	Hornyhead turbot
SD21	Longfin sanddab	Hornyhead turbot	Hornyhead turbot
RF3	Mixed rockfish	Mixed rockfish	Brown rockfish
RF4	Mixed rockfish	Honeycomb rockfish	Treefish

The species that were analyzed from each station are summarized in **Table 7.1**. The effort to collect targeted fishes was limited to 5 10-minute trawls at each trawl station. Occasionally, insufficient numbers of target species were obtained despite this effort. Only fish >13 cm standard length were retained for tissue analyses. These fish were sorted into no more than 3 composite samples per station, each containing a minimum of 3 individuals. Composite samples are typically made up of a single species; the only exceptions are samples that consist of mixed rockfish species. Fishes were then wrapped in aluminum foil, labeled, sealed in Ziplock bags, placed on dry ice, transported to the City's Marine Biology Laboratory, and held in the freezer at -80˚C until dissected.

Tissue Processing and Chemical Analyses

All dissections were performed according to standard techniques for tissue analysis. Each fish was partially defrosted and then cleaned with a paper towel to remove loose scales and excess mucus prior to dissection. The standard length (cm) and weight (g) of each fish were recorded (**Appendix E.1**). Dissections were carried out on Teflon pads that were cleaned between samples. Tissue samples were then placed in glass jars, sealed, labeled, and stored in a freezer at -20 °C prior to chemical analyses. All samples were subsequently delivered to the City of San Diego Wastewater Chemistry Laboratory within 10 days of dissection.

Tissue samples were analyzed for the chemical constituents specified by the permits under which this sampling was performed. These chemical constituents include trace metals, chlorinated pesticides, polychlorinated biphynel compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs), as listed in **Appendix E.2**. Values for individual constituents of pollutants reported as totals (e.g., total DDT) are listed in **Appendix E.3**. This report includes estimated values for some

parameters determined to be present in a sample with high confidence (i.e., peaks are confirmed by mass-spectrometry), but at levels below the MDL. A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Laboratory (City of San Diego 2007).

RESULTS AND DISCUSSION

Contaminants in Trawl-Caught Fishes

Metals

Ten metals, including arsenic, cadmium, chromium, iron, manganese, mercury, selenium, silver, tin, and zinc occurred in over 80% of the liver samples analyzed from fishes collected by trawl in 2006 (**Table 7.2**). Aluminum, antimony, barium, copper, lead, nickel, and thallium were also detected, but less frequently. Beryllium was not detected at all. Concentrations of most metals were <10 ppm. Exceptions occurred for arsenic, copper, iron, and zinc, which had concentrations above 15 ppm in at least one sample. Compared to all of the other metals, iron was relatively high in all 5 species of fish collected. In contrast, concentrations of zinc and copper were highest in California scorpionfish, and arsenic concentrations were highest in English sole and longfin sanddabs.

Intraspecific comparisons of the frequently detected metals between the 2 stations closest to the discharge (SD17, SD18) and those located farther away (SD15, SD16, SD19–SD21) suggest that there was no clear relationship between contaminant loads and proximity to the outfall (**Figure 7.2**). Contaminant concentrations were fairly similar across all stations and most were close to or below the maximum levels detected in the same species prior to discharge. Arsenic occurred at concentrations above the pre-discharge maximums in 15 of 40 samples. However, these samples were not concentrated near the outfall and occurred in multiple species.

Pesticides

Several chlorinated pesticides were detected during the 2006 surveys (**Table 7.3**). Individual components of total BHC, chlordane, and DDT are listed in Appendix E.2, while their detected values are included in Appendix E.3. DDT was found in all samples with total DDT concentrations ranging from about 46 to 1379 ppb. Other pesticides that were detected frequently included hexachlorobenzene (HCB) and chlordane. Maximum concentrations for these 2 contaminants were 3.5 and 215.8 ppb, respectively. As with metals, there was no clear relationship between concentrations of these pesticides and proximity to the outfall (**Figure 7.3**). In addition, most concentrations were close to or below the maximum levels detected in the same species prior to discharge. The only exceptions were 2 samples of California scorpionfish from outfall station SD17. California scorpionfish are known to migrate long distances (Hartmann 1987, Love et al. 1987), so it is unknown where these pesticides may have been acquired. These 2 samples also contained the only detectable concentrations of aldrin, alpha endosulphan, dieldrin, endrin, and BHC (lindane). Mirex was found in a single longfin sanddab sample from station SD16.

PAHs and PCBs

PAHs were not detected in fish liver samples during 2006. In contrast, PCBs occurred in every sample. All of the individual PAHs and PCB congeners that were analyzed are listed in Appendix E.2, while detected PCB congeners are summarized in Appendix E.3. Total PCB concentrations (i.e., the sum of all congeners detected in a sample, tPCB) were variable, ranging from about 18 to 1689 ppb (Table 7.3). There was no clear relationship between PCB concentrations and proximity to the outfall (Figure 7.3).

Contaminants in Fishes Collected by Rig Fishing

Arsenic, cadmium, chromium, iron, manganese, mercury, selenium, tin, and zinc occurred in at least 75% of the muscle tissue samples from various rockfish collected at rig fishing stations in 2006 (**Table 7.4**). Aluminum, antimony, barium, copper, nickel, and thallium were also detected, but in 50% or fewer of the samples. The metals with the highest concentrations included aluminum, arsenic, iron, and zinc. Each exceeded 2 ppm for at least one species of fish sampled. Iron and zinc had the

Table 7.2

Metals detected in liver tissues from fishes collected at SBOO trawl stations during 2006. Values are expressed as parts per million (ppm); n=number of detected values, nd=not detected.

	Al	Sb	As	Ba	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
California scorpionfish																	
N (out of 3)	2	nd	1	3	3	3	3	3	nd	2	3	2	3	3	nd	3	3
Min	2.09	—	5.05	0.055	2.29	0.11	12.5	49.7	—	2.30	0.168	0.101	0.69	0.097	—	1.64	110.0
Max	2.62	—	5.05	0.069	6.04	2.27	22.6	193.0	—	2.52	0.225	0.463	0.75	0.388	—	1.92	152.0
Mean	2.36	—	5.05	0.063	3.74	0.84	17.8	114.6	—	2.41	0.188	0.282	0.72	0.279	—	1.78	134.3
English sole																	
N (out of 6)	nd	nd	6	nd	6	5	nd	6	6	6	5	1	6	4	6	4	6
Min	—	—	8.66	—	0.57	0.11	—	132.0	0.52	1.33	0.056	0.117	1.10	0.057	1.46	0.26	29.2
Max	—	—	17.30	—	0.84	0.17	—	204.0	1.01	2.14	0.074	0.117	1.58	0.164	2.04	0.39	39.6
Mean	—	—	12.96	—	0.74	0.14	—	173.2	0.72	1.62	0.063	0.117	1.40	0.085	1.83	0.34	35.5
Hornyhead turbot																	
N (out of 20)	7	nd	19	13	20	16	13	20	1	20	20	6	20	20	7	20	20
Min	1.13	—	0.83	0.026	2.00	0.10	4.1	5.0	0.32	0.34	0.073	0.098	0.39	0.071	1.58	0.27	34.1
Max	6.14	—	7.37	0.149	6.24	0.88	14.9	127.0	0.32	2.19	0.156	0.745	1.15	0.515	2.39	1.96	87.5
Mean	2.84	—	3.66	0.062	3.64	0.29	9.5	49.5	0.32	1.35	0.100	0.218	0.80	0.268	2.01	0.99	58.1
Longfin sanddab																	
N (out of 10)	4	5	10	4	10	8	5	10	2	9	10	2	10	10	6	10	10
Min	2.01	0.26	1.90	0.078	0.30	0.08	0.1	42.8	0.35	0.21	0.031	0.096	0.27	0.076	2.35	0.30	15.6
Max	7.14	0.66	16.30	0.116	3.95	0.83	7.1	180.0	0.38	2.49	0.135	0.759	1.77	0.346	2.99	2.57	29.0
Mean	5.41	0.51	8.12	0.099	1.54	0.36	4.0	99.6	0.37	1.34	0.074	0.428	1.00	0.221	2.67	1.22	23.8
Pacific sanddab																	
N (out of 1)	nd	nd	nd	1	1	1	1	1	nd	1	1	nd	1	1	nd	1	1
Min	—	—	—	0.087	1.90	0.65	4.3	60.8	—	2.11	0.081	—	0.51	0.198	—	3.09	25.4
Max	—	—	—	0.087	1.90	0.65	4.3	60.8	—	2.11	0.081	—	0.51	0.198	—	3.09	25.4
Mean	—	—	—	0.087	1.90	0.65	4.3	60.8	—	2.11	0.081	—	0.51	0.198	—	3.09	25.4
ALL SPECIES																	
% Detected	33	13	90	53	100	83	55	100	23	95	98	28	100	95	48	95	100
Max Value	7.14	0.66	17.30	0.149	6.24	2.27	22.6	204.0	1.01	2.52	0.225	0.759	1.77	0.515	2.99	3.09	152.0

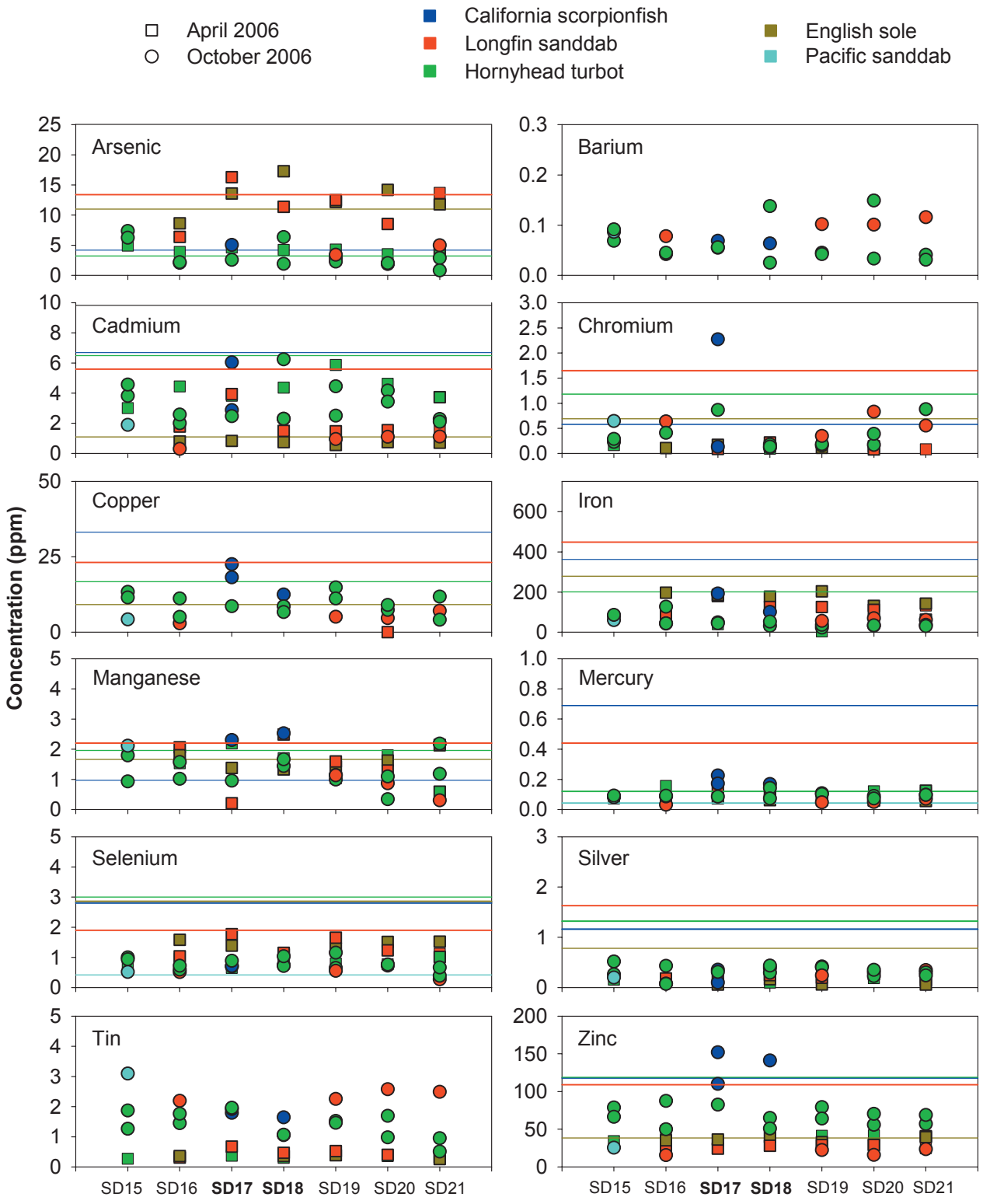

Figure 7.2

Concentrations of frequently detected metals in liver tissues of fishes collected from each SBOO trawl station during 2006. Reference lines are maximum values detected during the pre-discharge period (1995–1998); tin and barium were not detected during this period because of substantially higher detection limits. Therefore no reference lines are present for these contaminants. Stations closest to the discharge site are labeled in bold.

Table 7.3

Chlorinated pesticides, total PCB, and lipids detected in liver tissues from fishes collected at SBOO trawl stations during 2006. Alpha enosulphan=(a)E; hexachlorobenzene=HCB; total BHC (lindane)=tBHC; total chlordane=tChlor, total DDT=tDDT; total PCB=tPCB. Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt), n=number of detected values, nd=not detected.

	Pesticides										
	Aldrin	**(a)E**	**Dieldrin**	**Endrin**	**HCB**	**Mirex**	**tBHC**	**tChlor**	**tDDT**	**tPCB**	**Lipids**
California scorpionfish											
N (out of 3)	2	2	2	2	2	nd	2	3	3	3	3
Min	5.1	8.3	14	44	1.2	—	97.0	6.1	308.1	124.3	16.4
Max	19.0	9.6	63	66	1.9	—	278.0	215.8	1379.0	387.7	32.2
Mean	12.1	9.0	38.5	55	1.6	—	187.5	113.6	706.1	218.6	23.6
English sole											
N (out of 6)	nd	nd	nd	nd	5	nd	nd	1	6	6	6
Min	—	—	—	—	0.4	—	—	1.4	65.4	41.8	2.4
Max	—	—	—	—	0.7	—	—	1.4	161.3	82.3	5.7
Mean	—	—	—	—	0.5	—	—	1.4	114.0	58.8	4.4
Hornyhead turbot											
N (out of 20)	nd	nd	nd	nd	11	nd	1	4	20	20	20
Min	—	—	—	—	0.4	—	5.9	0.8	45.5	18.0	2.7
Max	—	—	—	—	0.9	—	5.9	5.4	198.2	62.1	13.2
Mean	—	—	—	—	0.7	—	5.9	2.9	93.0	36.6	8.4
Longfin sanddab											
N (out of 10)	nd	nd	nd	nd	10	1	nd	10	10	10	10
Min	—	—	—	—	1.4	2.6	—	3.1	397.0	174.1	12.1
Max	—	—	—	—	3.5	2.6	—	26.8	1260.3	1689.0	62.4
Mean	—	—	—	—	2.3	2.6	—	15.7	749.9	478.9	31.7
Pacific sanddab											
N (out of 1)	nd	nd	nd	nd	1	nd	nd	1	1	1	1
Min	—	—	—	—	2.4	—	—	15.3	254.6	113.9	37.4
Max	—	—	—	—	2.4	—	—	15.3	254.6	113.9	37.4
Mean	—	—	—	—	2.4	—	—	15.3	254.6	113.9	37.4
ALL SPECIES											
% Detected	5	5	5	5	73	3	8	48	100	100	100
Max Value	19.0	9.6	63	66	3.5	2.6	278.0	215.8	1379.0	1689.0	62.4

highest values at 25.6 and 15.5 ppm, respectively. Both of these concentrations occurred in samples of Brown rockfish. DDT and PCB were detected in 100% of the muscle samples, while the pesticides HCB, aldrin, dieldrin, endrin, BHC (lindane), and chlordane were found much less frequently (**Table 7.5**). Each of these contaminants was detected in relatively low concentrations, from 0.1 ppb for HCB to 22.8 ppb for total DDT.

To address human health concerns, concentrations of constituents found in muscle tissue samples were compared to both national and international limits and standards (Table 7.4, Table 7.5). The United States Food and Drug Administration (FDA) has set limits on the amount of mercury, total DDT, and chlordane in seafood that is to be sold for human consumption and there are also international standards for acceptable concentrations of various metals (see Mearns et al. 1991). Of the compounds detected in the fish muscle tissues collected as part of the SBOO monitoring program, only arsenic, cadmium, and selenium had concentrations slightly higher than international standards.

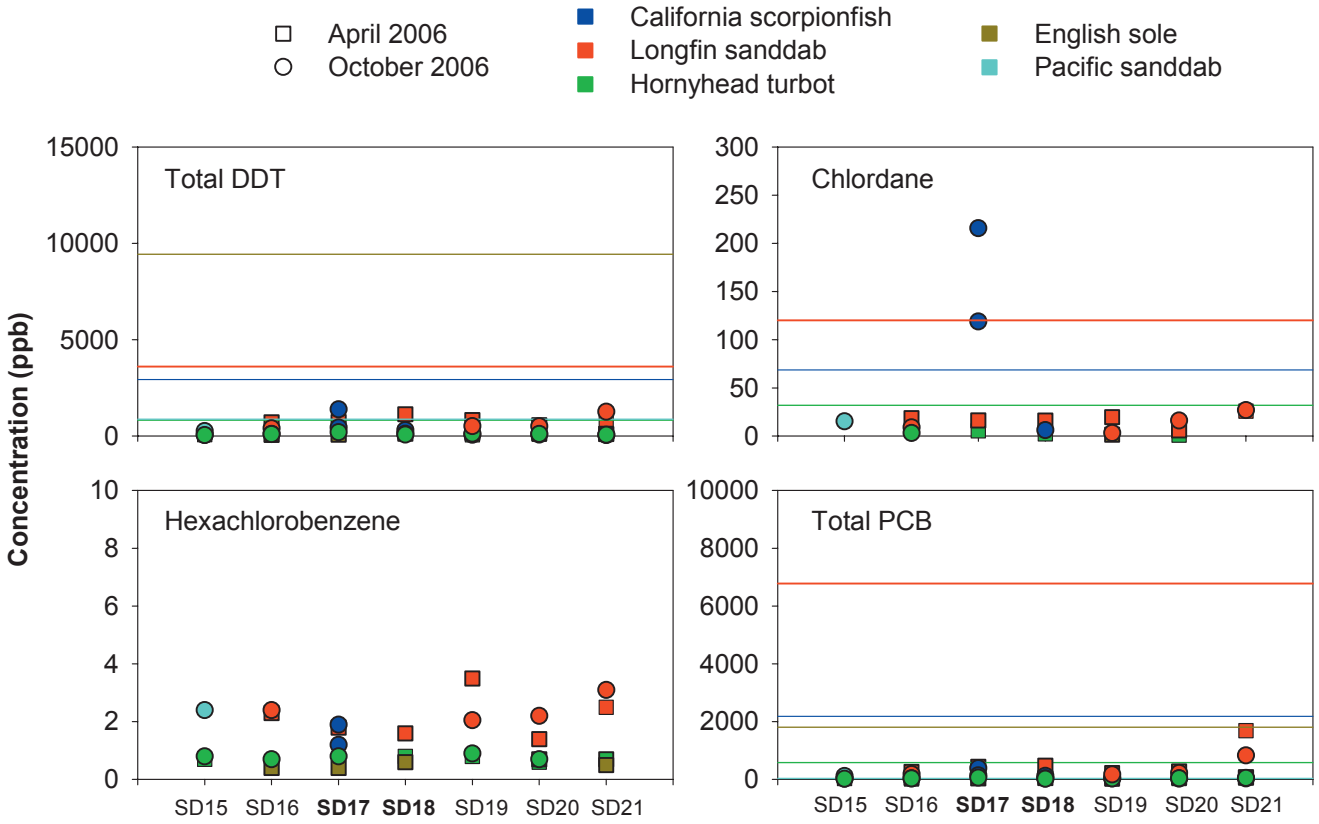

Figure 7.3

Concentrations of frequently detected chlorinated pesticides (total DDT, chlordane, hexachlorobenzene) and total PCBs in liver tissues of fishes collected from each SBOO trawl station during 2006. Reference lines are maximum values detected during the pre-discharge period (1995–1998); chlordane and hexachlorobenzene were not detected as frequently during this period because of substantially higher detection limits. Therefore reference lines for these 2 contaminants are absent for some or all of the species. Stations closest to the discharge site are labeled in bold.

In addition to addressing health concerns, spatial patterns were assessed for total DDT and total PCB, as well as all metals that occurred frequently in muscle tissue samples (**Figure 7.4**). Overall, concentrations of DDT, PCB, and metals were fairly similar in the muscle tissues from fishes at both rig fishing stations suggesting there was no evident relationship with proximity to the outfall.

Comparison of contaminant loads between RF3 and RF4 should be considered with caution however, because different species of fish were collected at the 2 sites. All specimens belong to the family Scorpaenidae and have similar life histories (i.e., bottom dwelling tertiary carnivores), and therefore have similar mechanisms of exposure (e.g., exposure from direct contact with the sediments and through possibly similar food sources). However, different species can have different physiologies and diet that could affect the accumulation of contaminants.

SUMMARY AND CONCLUSIONS

Ten trace metals, DDT, and a combination of PCBs were each detected in over 75% of the liver samples from 5 species of fish collected around the South Bay Ocean Outfall (SBOO) in 2006. All contaminant values were within the range of those reported previously for the Southern California Bight (SCB) (see Mearns et al. 1991, City of San Diego 1996–2001, Allen et al. 1998). Although several individual samples contained concentrations of some trace metals that exceeded pre-discharge

Table 7.4

Metals detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2006. Data are compared to U.S. FDA action limits and median international standards for parameters where these exist. Bold values exceed these standards, n=number of detected values, nd=not detected.

	Al	Sb	As	Ba	Cd	Cr	Cu	Fe	Mn	Hg	Ni	Se	Tl	Sn	Zn
Brown rockfish															
N (out of 4)	1	1	4	1	3	2	1	4	3	4	1	4	3	3	4
Min	5.40	0.74	0.60	0.034	0.03	0.13	0.334	2.13	0.10	0.12	0.10	0.20	1.09	0.29	2.81
Max	5.40	0.74	**2.39**	0.034	**1.21**	0.51	0.334	25.60	0.27	0.16	0.10	0.23	1.82	1.60	15.50
Mean	5.40	0.74	1.16	0.034	0.46	0.32	0.334	9.58	0.17	0.14	0.10	0.22	1.54	0.74	6.55
California scorpionfish															
N (out of 3)	nd	nd	3	nd	1	2		3	1	3	nd	3	3	3	3
Min	—	—	**2.85**	—	0.03	0.10		0.33	0.22	0.12	—	**0.32**	1.81	0.13	3.07
Max	—	—	**5.77**	—	0.03	0.20		1.90	0.22	0.20	—	**0.98**	1.99	0.33	3.22
Mean	—	—	**4.32**	—	0.03	0.15		1.22	0.22	0.15	—	**0.70**	1.90	0.26	3.15
Honeycomb rockfish															
N (out of 1)	1	1	1	1	1	1	1	1	1	1	1	1	nd	1	1
Min	7.44	0.80	**5.32**	0.044	0.17	0.42	0.591	2.82	0.17	0.10	0.19	**0.33**	—	1.70	4.84
Max	7.44	0.80	**5.32**	0.044	0.17	0.42	0.591	2.82	0.17	0.10	0.19	**0.33**	—	1.70	4.84
Mean	7.44	0.80	**5.32**	0.044	0.17	0.42	0.591	2.82	0.17	0.10	0.19	**0.33**	—	1.70	4.84
Mixed rockfish															
N (out of 3)	2	3	3	3	3	3	3	3	3	3	3	3	nd	3	3
Min	2.18	0.85	1.30	0.033	0.13	0.38	0.474	2.01	0.09	0.05	0.15	0.29	—	1.54	4.10
Max	6.11	1.07	**1.83**	0.041	0.16	0.43	0.543	5.89	0.14	0.18	0.22	**0.41**	—	1.72	5.65
Mean	4.15	0.93	**1.62**	0.037	0.15	0.41	0.509	3.85	0.12	0.10	0.18	**0.35**	—	1.64	4.79
Treefish															
N (out of 1)	1	1	1	1	1	1	1	1	1	1	1	1	nd	1	1
Min	4.37	0.83	**1.43**	0.038	0.13	0.38	0.473	4.19	0.08	0.23	0.17	**0.41**	—	1.80	5.20
Max	4.37	0.83	**1.43**	0.038	0.13	0.38	0.473	4.19	0.08	0.23	0.17	**0.41**	—	1.80	5.20
Mean	4.37	0.83	**1.43**	0.038	0.13	0.38	0.473	4.19	0.08	0.23	0.17	**0.41**	—	1.80	5.20
ALL SPECIES															
% Detected	42	50	100	50	75	75	50	100	75	100	50	100	50	92	100
Max Value	7.44	1.07	5.77	0.044	1.21	0.51	0.591	25.60	0.27	0.23	0.22	0.98	1.99	1.80	15.50
US FDA Action Limit*										1.00					
Median IS*			1.4		1.0	1.0	20			0.5		0.3		175	70

* From Mearns et al. 1991. FDA mercury action limits and all international standards (IS) are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

Table 7.5

Total PCB, chlorinated pesticides, and lipids detected in muscle tissues from fishes collected at SBOO rig fishing stations during 2006. Hexachlorobenzene=HCB; total BHC (lindane)=tBHC; total chlordane=tChlor, total DDT=tDDT; total PCB=tPCB Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt); n=number of detected values, nd=not detected. Data are compared to U.S. FDA action limits and median international standards for parameters where these exist.

	Pesticides								
	HCB	Aldrin	Dieldrin	Endrin	tBHC	tChlor	tDDT	tPCB	Lipids
Brown rockfish									
N (out of 4)	1	nd	nd	nd	nd	nd	4	4	4
Min	0.1	—	—	—	—	—	2.4	0.9	0.1
Max	0.1	—	—	—	—	—	4.8	4.8	0.5
Mean	0.1	—	—	—	—	—	3.3	2.1	0.3
California scorpionfish									
N (out of 3)	nd	1	1	1	1	1	3	3	3
Min	—	1.3	2.8	2.9	19.0	14.9	3.6	0.6	0.4
Max	—	1.3	2.8	2.9	19.0	14.9	9.2	1.1	1.4
Mean	—	1.3	2.8	2.9	19.0	14.9	5.7	0.9	0.8
Honeycomb rockfish									
N (out of 1)	1	nd	nd	nd	nd	nd	1	1	1
Min	0.1	—	—	—	—	—	7.8	2.1	0.8
Max	0.1	—	—	—	—	—	7.8	2.1	0.8
Mean	0.1	—	—	—	—	—	7.8	2.1	0.8
Mixed rockfish									
N (out of 3)	1	nd	nd	nd	nd	2	3	3	3
Min	0.1	—	—	—	—	0.2	2.0	0.6	0.5
Max	0.1	—	—	—	—	0.3	13.4	3.0	3.0
Mean	0.1	—	—	—	—	0.3	7.1	2.0	1.5
Treefish									
N (out of 1)	nd	nd	nd	nd	nd	1	1	1	1
Min	—	—	—	—	—	0.6	22.8	4.9	1.3
Max	—	—	—	—	—	0.6	22.8	4.9	1.3
Mean	—	—	—	—	—	0.6	22.8	4.9	1.3
ALL SPECIES									
% Detected	25	8	8	8	8	33	100	100	100
Max Value	0.1	1.3	2.8	2.9	19.0	14.9	22.8	4.9	3.0
US FDA Action Limit*						300	5000		
Median IS*						100	5000		

* From Mearns et al. 1991. FDA action limits for total DDT and chlordane are for fish muscle tissue and all international standards (IS) are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

maximum values, the concentrations of most contaminants were not substantially different from pre-discharge data (City of San Diego 2000b). In addition, the few samples that did exceed these pre-discharge values were distributed widely among the sampled stations and showed no pattern relative to wastewater discharge.

The frequent occurrence of metals and chlorinated hydrocarbons in SBOO fish tissues may be due to many factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB. In fact, many metals occur naturally in the environment (see chapters 4 and 8), although little

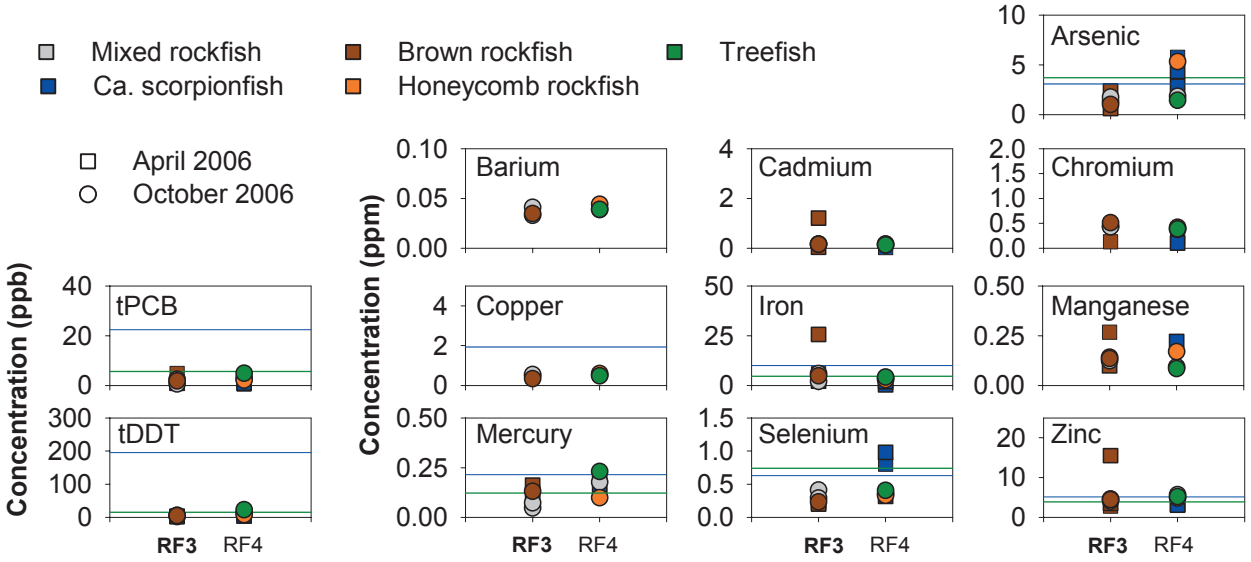

Figure 7.4

Concentrations of frequently detected metals, total DDT, and total PCB in muscle tissues of fishes collected from each SBOO rig fishing station during 2006. Missing data represent concentrations below detection limits. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for California scorpionfish and mixed rockfish. Honeycomb rockfish, treefish, and brown rockfish were not collected during that period. Station RF3 is the station closest to the discharge site.

information is available on their background levels in fish tissues. Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants to be considered reference sites. This has been supported by more recent work regarding PCBs and DDTs (e.g., Allen et al. 1998, 2002). The lack of contaminant-free reference areas in the SCB clearly pertains to the South Bay region, as demonstrated by the presence of many contaminants in fish tissues prior to wastewater discharge (City of San Diego 2000b).

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species. For example, exposure to contaminants can vary greatly between species and among individuals of the same species depending on migration habits (Otway 1991). Fish may be exposed to contaminants in one highly contaminated area and then move into an area that is less contaminated. This is of particular concern for fishes collected in the vicinity of the SBOO, as there are many point and non-point sources that may contribute to contamination in the region (see Chapters 2–4). For example, some monitoring stations are located near the Tijuana River, San Diego Bay, and dredged materials disposal sites, and input from these sources may affect fish in surrounding areas.

Overall, there was no evidence that fishes collected in 2006 were contaminated by the discharge of wastewater from the SBOO. While some muscle tissue samples from sport fish collected in the area had concentrations of arsenic, cadmium, and selenium above the median international standard for shellfish, concentrations of mercury and DDT were below FDA human consumption limits. Finally, there was no other indication of poor fish health in the region, such as the presence of fin rot or other physical anomalies (see Chapter 6).

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